

Application No. 09/821,410
Amndt. dated: January 4, 2005
Reply to Office Action mailed: October 4, 2004

Amendments to the Specification:

Please replace paragraph [0014] beginning at page 5, line 13, with the following rewritten paragraph:

- [0014] Embodiments of the present invention also include generating a training signal sequence and transmitting the training signal sequence over a transmission media channel to generate an observed or measured output signal; ~~convolving the training sequence with an unknown impulse response representation of the transmission media channel to form a computed output signal of the channel, and minimizing a~~ A minimized difference value between an the observed or measured output signal of the channel and a signal value representation of convolution of the training signal sequence and the unknown impulse response of the channel, together with the computed output signal of the channel. ~~The method also includes using the minimized difference, the training signal sequence, and the observed or measured output signal to compute an initial impulse response of the channel. Further refinements or fine-tuning of the impulse response then can be done using other known convergence techniques.~~ - -

Please replace paragraph [0019] beginning at page 7, line 13, with the following rewritten paragraph:

[0019] In accordance with an embodiment of the invention, a correlation based technique for rapidly identifying (i.e., estimating or determining) the impulse response of a transmission media channel is provided. The identification is used for rapid initial training of an echo canceller and a channel equalizer after which other known techniques can be used for further training, as will be described below. The technique of the present invention works as follows. Assume a known time domain sequence

$$x = [x_0, x_1, \dots, x_{T-1}]$$

is an input to a transmission media channel 10 as a training sequence, as shown in Fig. 1. The sequence can be a series of wide-band pseudo-random time domain signals of length T, as will be appreciated by those skilled in the art. The transmission channel 10 in Fig. 1 has

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an unknown impulse response $h(n)$, for $n=0$ to $N-1$, and $y(k)$ is the observed or measured output for $k=0$ to $T-(N+1)$, where N is the number of coefficients of the impulse response h to be determined. Then, the output of the transmission channel 10 can be expressed as

$$y_k = \sum_{n=0}^{N-1} h_n x_{k+n} + g_k, \quad (1)$$

where g_k is a signal noise component. Mathematically, Equation (1) is the convolution of the transmission channel's unknown impulse response h and the known input sequence x . Equation (1) can also be represented in matrix notation as

$$Y = XH + G, \quad (2)$$

where X is a matrix with elements

$$X_{[k][n]} = X_{k+n}$$

For certain applications, it is reasonable to neglect the noise component because its effects are not as severe as the channel impairments on the received signal. Doing so and letting E be the squared error vector of the difference between the actually observed or measured channel output Y (which is a function of the actual h and x), and the computed an output signal value representation XH , the error vector E can be expressed as

$$\begin{aligned} E &= |Y - XH|^2 \quad (4) \\ &= (Y - XH)(\overline{Y - XH}) \\ &= Y\overline{Y} - Y(\overline{XH}) - (XH)\overline{Y} + (XH)(\overline{XH}) \\ &= Y\overline{Y} + \overline{H}X^H XH - \overline{Y}(XH) - (\overline{H}X)Y, \end{aligned}$$

where the "bar" over a term indicates the Hermetian of that matrix or vector. To minimize the squared error, the partial derivative of the error vector E with respect to H is equated with zero, as

$$\frac{\partial E}{\partial h_n} = 2\overline{X}XH - 2\overline{X}Y = 0 \quad (5)$$

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Equation (5) can be rearranged as

$$2\overline{X}XH = 2\overline{X}Y$$

or

$$H = (\overline{X}X)^{-1}\overline{X}Y,$$

where

$$(\overline{X}X)^{-1}$$

is a square symmetric matrix. Setting

$$M = (\overline{X}X)^{-1}\overline{X} \quad (6)$$

gives

$$H = MY \quad (7)$$

Thus, the impulse response of the transmission media channel can be expressed as a product of the matrix M , which depends solely on the known input training sequence X , and the observed or measured output vector Y . In other words, the matrix M operates on the vector Y to give the channel's impulse response. As will be appreciated by those skilled in the art, if the length of the input sequence x is T and the length of the channel impulse response is N (i.e., N is the number of coefficients needed to span the length of the channel's impulse response), then M is a $(T-N) \times N$ matrix and $(\overline{X}X)^{-1}$ is an $N \times N$ square symmetric matrix.